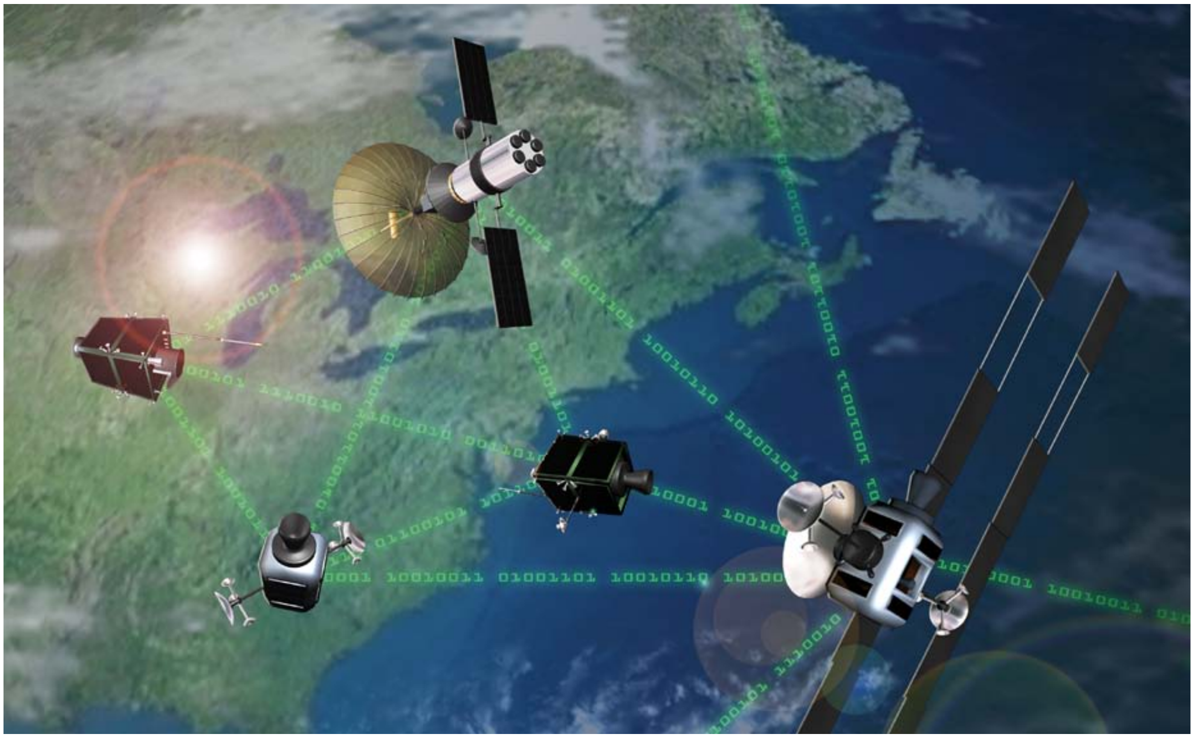
DARPA's System F6 Program

Demonstrating Spacecraft Fractionation



The Future, Fast, Flexible, Free-Flying, Fractionated (F6) spacecraft program will perform an in-space demonstration of the technologies for spacecraft fractionation. Fractionation involves flying a cluster of satellites that are linked together via a wireless network, creating a *virtual spacecraft* with the same or better capability than a traditional monolithic, multi-payload spacecraft. Each spacecraft module carries some combination of individual payloads and/or satellite resources that are available for use by the entire cluster, such as data processing and storage, hardware for communication with nodes on the ground, cluster navigation sensors, or redundant hardware. These resources are dynamically allocated as needed, creating a flexible and robust infrastructure that can seamlessly integrate multiple payloads.

Fractionated architectures offer significant benefits in flexibility and robustness that cannot be achieved using conventional architectures. A monolithic satellite with multiple payloads cannot launch until all the payloads complete development. Delays in just one payload result in an overall program delay, even if all the other components and payloads are on schedule. As the number of payloads, the probability that at least one will be delayed increases, thus costs tend to grow. A fractionated architecture can launch modules individually, therefore delays with the development of one payload will only impact the launch of its host module. The remaining modules can be launched on schedule, immediately performing their mission and delivering value to the end user.

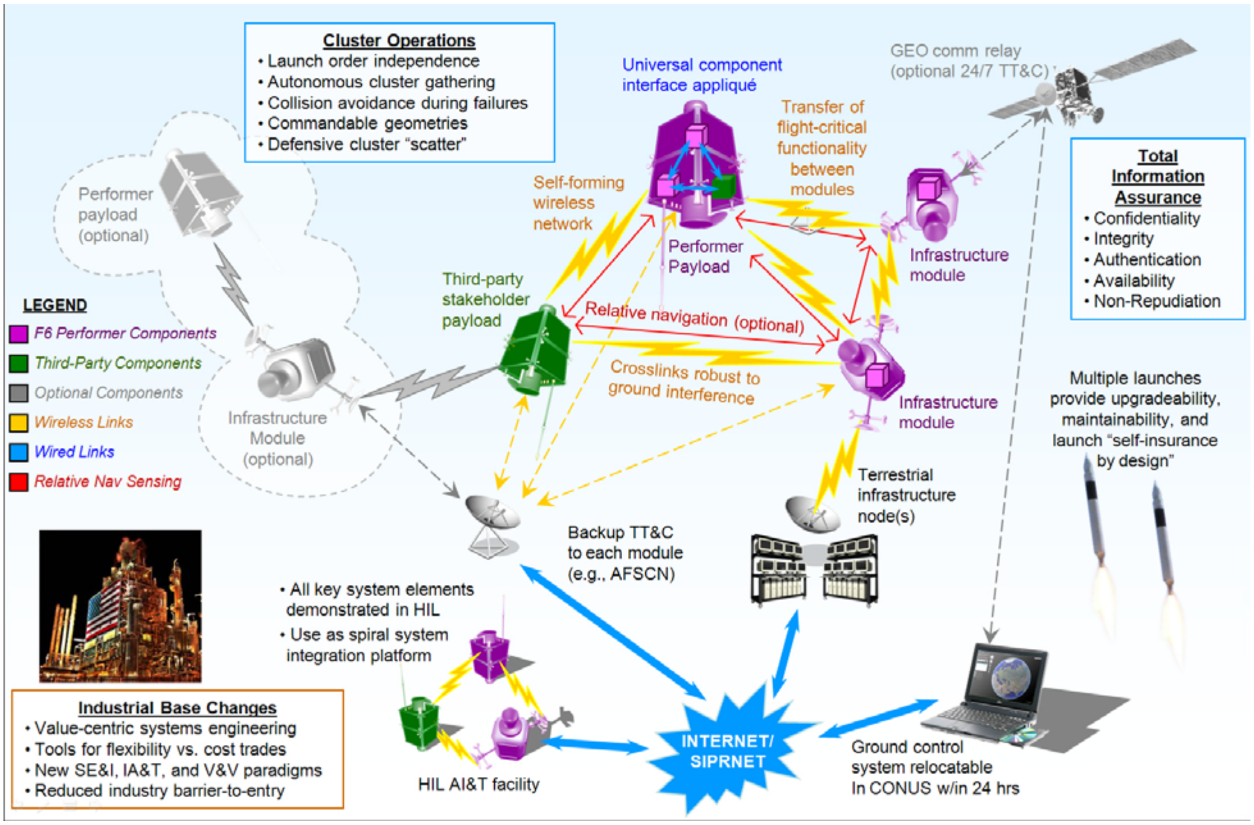
This concept of independently launching each module creates an architecture that is much more flexible than conventional architectures. Should a payload or resource fail on-orbit, the cost of replacing a module with a replacement component is significantly lower than the cost of an entire replacement monolith. New modules can also add capability to the system, either by introducing upgraded technology (e.g. processors that take advantages of improvements since the system was originally launched) or adding new capabilities or payloads. Independent launch of smaller modules also leads to a system that is more survivable, as a failure of a single launch vehicle cannot take out the entire cluster.

Fractionated architectures can be assembled with spacecraft of any size, but notionally these modules will be significantly smaller than conventional monoliths. This reduces the barrier to entry for smaller spacecraft developers, who can contribute elements of the overall architecture, thus strengthening the industrial base. Even large spacecraft can participate in fractionated clusters through the incorporation of a *fractionation suite* into the spacecraft bus design. This hardware will allow a conventional bus to act as a fractionated resource within a cluster, allowing the payloads to utilize the resources available elsewhere on the cluster. These *fractionated monoliths* represent a solid first step in the transition path from conventional architectures to more flexible, robust, fully fractionated architectures.

Developing the first fractionated spacecraft systems requires advances in several key technology areas, including first-of-a-kind demonstrations of autonomous multi-body cluster operations and implementation of distributed spacecraft avionics and resource sharing. F6 will perform autonomous, de-centralized, real-time multi-body relative motion planning with 3 or more spacecraft, and perform precise relative multi-body position and attitude sensing with carrier-phase differential GPS. F6 will also demonstrate spacecraft avionics resource prioritization and allocation using dynamic networks with time-varying Quality of Service (QoS) capabilities.

F6 will develop and demonstrate a space-qualified transceiver for 24/7 space-to-ground communication capability in low Earth orbit (LEO) utilizing a commercial GEO communications satellite. Current LEO vehicles can utilize TDRSS or other GEO communication relays, but these are typically scheduled in advance and subject to prioritization constraints which limit the overall availability. The Inmarsat transceiver being developed for F6 has heritage to terrestrial and airborne hardware, but has unique challenges associated with the space environment and Doppler shifts in low Earth orbit.

The F6 demonstration will include three DARPA modules launched into a LEO orbit. The demonstration cluster will include two infrastructure modules and one payload module (see figure). Each infrastructure module carries resources that are available to the entire cluster; the payload module may contain some infrastructure components, but will also carry one or more payloads. These payloads will be provided by stakeholders or transition partners, and will be selected based on the data needs of the stakeholders, the flight readiness of the payload, and the ability of the payload to demonstrate the full range of capability of the fractionated inter-spacecraft cluster. In addition, the F6 cluster will also be capable of accommodating one or more full spacecraft modules supplied by third-party (non-DARPA) stakeholders. The 3rd party modules interface with the cluster via the open standards defined in the F6 Developer's Kit, which will describe the required interfaces (including wireless communications, networking, resource sharing, and cluster operations) between modules. DARPA is very interested in opening a dialog with additional stakeholders about providing payloads and/or full modules for the F6 demonstration.



The F6 program began in February 2008 with a 12-month Phase 1 study that concluded with a Preliminary Design Review and a full-scale system simulation of all elements of the architecture. In September 2009, F6 will begin detailed design work and additional technology development activities, culminating in a Conceptual Design Review and a breadboard-level Hardware-In-The-Loop system demonstration in September 2010. Launch of the first two modules is scheduled for late 2012.

Fractionation has the potential to significantly improve the performance, value, flexibility, and robustness of future satellite systems. By maturing key fractionation technologies and performing a successful on-orbit demonstration, DARPA will show the benefits of a fractionated architecture for future space systems.

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